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Σ hyperons in nuclear collisions at energy of few GeV/c

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Abstract. The perspectives of identifying and studying the mechanisms of Σ hyperons production (isotopic and charged ratios) at the Nuclotron are discussed. The study of ion-ion interactions at few GeV/c per nucleon energy is interesting for searching new a phenomena and phase transitions at high baryonic densities and moderate temperatures of nuclear matter. In this paper, the possible extension of physical program of the planned measurements is considered.

1 Introduction

Nuclear matter at high baryon densities and moderate temperatures is the interesting region for searching new phase transition and new phenomena. The study of the production mechanism of strange particles can give us more information about the state of matter. Strangeness is conserved during the strong interactions, so strange and anti-strange quarks are produced in pairs. In the vacuum state this fact leads to the equation of production cross section for K^+ and K^-, but in the baryonic-rich matter this symmetry is disturbed by K^+, which appears with hyperons, especially at relatively small initial energies (shown in Tab. 1). It is a simple kinematic effect. The mass difference between K^+ and pion is 354.2 MeV, the mass difference between Σ^+ and proton is 251.1 MeV, and for Λ and neutron it is 176.1 MeV. For strange hyperon production it does not need to produce an additional particle – it is enough to "change" one nucleon quark to the strange one. This fact can influence on particle production cross section ratios including strange and wide-discussed $K^+/\ \pi^+$. To illustrate the effect, we can use the UrQMD model. The total amount of K^+ and K^0 (13625) produced in 3AGeV with 5 % precision corresponds to the total amount of Λ and Σ hyperons (13035). In this case, these six hadrons compose the system, which can compensate strange quarks and strange anti-quarks. At higher collision energies the asymmetry for quarks and anti-quarks is decreased, but at energies up to 10AGeV the absence of at least one particle in these particle sets leads to the non-compensated for strangeness system. Up to now, Σ baryons are included in lists of identified particles, but only as unseparated addition of Σ^0 to the Λ production.

The UrQMD model also predicts the Σ^0/Λ ratio dependence on the initial energy for C-C interaction (shown in Tab. 2). This ratio grows with increasing the energy, and from about 5 GeV/n this growth stops and then falls down to the constant value.

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Table 1. Total amount of produced particles for 10^5 C-C interaction at different energies from UrQMD model

C-C,UrQMD	2AGeV	3AGeV	4AGeV	10AGeV	30AGeV
All particles	2968383	3269875	3555732	4785049	6861519
p^+	980372	973357	964317	934470	899765
n^0	982267	974936	965797	937139	900696
Λ	1393	5493	10405	30537	57559
Σ^+	489	2347	4389	11135	17909
Σ^0	623	2918	5653	12424	19557
Σ^-	549	2277	4321	11209	18108
π^+	178772	269480	354107	714208	1286150
π^0	205822	312142	407661	796030	1418912
π^-	178205	267809	354088	713459	1286178
K^+	1607	6884	13574	45080	108427
K^0	1506	6741	13218	44376	108090
$\overline{K}^0$	30	279	942	11760	51677
K^-	27	279	918	11516	51639

Table 2. Σ^0/Λ ratio in C-C collision from UrQMD model

E_0, AGeV	1.5	2	3	3.5	4	6	8	10	30	100
Σ^0/Λ	0.31	0.45	0.53	0.52	0.54	0.47	0.43	0.41	0.34	0.32

2 Status of hyperon reconstruction

The measurement of the heavy baryon production cross sections (Σ and Λ) in A-A collisions at energies of few GeV/c can be performed by means of the BM@N(JINR) experiment. It is necessary to identify neutrons and gammas for the hyperon reconstruction. This information about neutral particles can be obtained via the electromagnetic calorimeter (ECal) of the BM@N. This calorimeter is an essential component of the BM@N detector, which makes contributions to the different fields of physics. This is the "shashlyk"-type calorimeter, constructed from separated modules. The "shashlyk" module is a lead-scintillator sandwich. Based on the different A-A (C, Kr, Ar) experimental data from March 2018, the analysis of the electromagnetic calorimeter data was started. After the preliminary calibration (during the 55 run) the beam calibration on MIP position in every module was done. For this, we apply cuts on energy photon spectra in each calorimeter central cell and 8 cells around:

$$k = \frac{A_0}{\sum_{i=1}^{i=8}(Ai)}$$

where is k=0.10%, 0.20%,0.30% and others, A_0 - amplitude in central cell. These cuts are shown in Fig. 1. According to these values, the most reasonable cuts are about 10-40% for the sum of the surrounding cells related to the central one. This method can separate the peak of one-charged particles (MIP), which can be use for the energy calibration of the whole electromagnetic calorimeter. Also, in some channels (which are closer to the beam) the peak of double-charged particles can be separated. Preliminary beam calibrations for a half of ECal are shown in Fig. 2. The position of the one-charged peak in each cells was corrected for one chosen cell position manually, and after this calibrations coefficients were applied to the double-charged peak (for channels where it can be defined). These coefficients improved

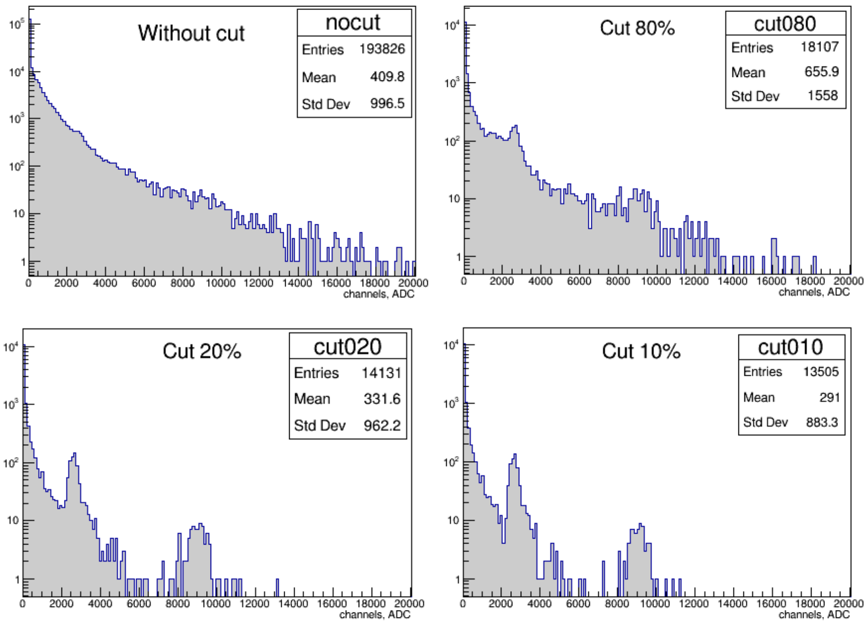

Figure 1. Different cut on energy in 9 calorimeter cells

the double-charge peak position too. This procedure can give association with the spectra in ADC channels to energy-axis for the further pion reconstruction. In Fig. 3 the sum of the spectra is shown in the ECal channels after applying the beam calibrations. The one-charged and double-charged peaks are good separeted. This picture is made with 20% cut on energy in the around cells.

The main problem with the beam calibrations is the different position of calorimeter cells in respect to the beam-axis. In the channels which were too far from the beam the photon spectra does not allow to separate the MIP peak to calibrate them. To resolve this problem the calibration on the cosmic particles was done. For the part of the channels where both calibration coefficients are found, these two methods give a good agreement. Thereby, all the channels of Ecal can be calibrated for the further analysis. The method of cluster separation was developed and tested using the Monte-Carlo data. The reconstruction of pions from the experimental data via the electromagnetic calorimeter is under way.

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References

[1] G. Van Buren, for the STAR Collaboration, *The ratio* Σ/Λ *at RHIC, STAR collaboration*, arXiv:nucl-ex/0512018 (2005)

[2] COSY-TOF collaboration, *Production of* Λ *and* Σ *hyperons in proton-proton collisions*, arXiv:1008.4287 [nucl-ex] (2010)

[3] A.V. Anisovich et al., Int.J.Mod.Phys. A **25**(16), 3155-3171 (2010). arXiv:1002.1577[hep-ph] (2010)

https://doi.org/10.1051/epjconf/201920403016

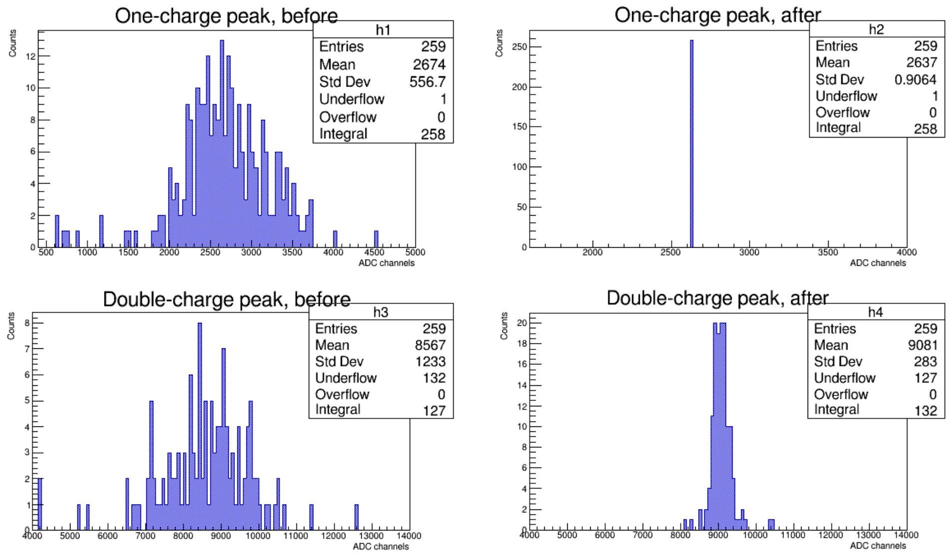

Figure 2. Preliminary beam calibration

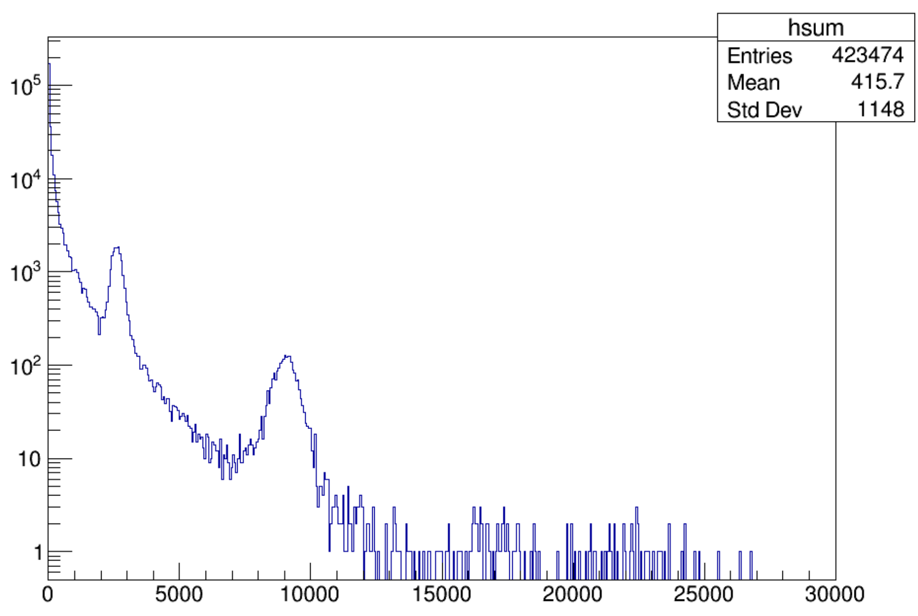

Figure 3. Photon spectra, sum of calibrated channels